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Laser Level

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Background of Invention:

The present invention relates generally to leveling instruments, and more particularly, relates to a laser leveling instrument capable of multiple modes of operation. The present invention is related to Disclosure Document No. 366475, entitled, Laser Level, filed on December 8, 1994.

Laser levels have been used in construction for many years. They typically seek to produce a plane of light for a reference for construction projects. Laser levels have been used for large scale construction projects like commercial excavating, laying foundations, and installing drop ceilings. Laser levels save considerable time during initial layout of a construction job compared to other tools such as beam levels, chalk lines, or torpedo levels. Some examples of jobs where laser levels would be useful include laying tile, mounting cabinets, installing counter tops, and building outdoor decks. Because these laser levels can typically cost thousands of dollars, only those who regularly land larger construction projects can justify purchasing a laser level. Laser levels have not achieved widespread adoption by the general public despite the time savings because of their initial cost of ownership. The expense can be attributed to the cost of suitable laser sources such as He-Neon laser and associated optical system used to manipulate the beam generated by the laser source.

Summary of Invention:

The present invention relates to a laser level instrument. In one embodiment, the present invention employs a laser diode module as the laser source and optical system. The present invention can generate a level plane of light or a level line of light which can be a layout reference. Instead of defining an optical path by using expensive optical components and complex alignment procedures to manipulate the laser beam, the invention is capable of using relatively inexpensive optical components and novel alignment procedures to permit use of laser diode modules. In another feature, the invention provides a novel method where the existing laser beam output from a low cost laser diode module can be aligned to be perpendicular to the rotational axis of the laser level instrument. The method can dramatically decrease the cost of the necessary optical system used in the laser level. Thus the cost barrier which prevents the public from adopting the laser level as a general purpose tool is greatly reduced.

In a feature of the present invention, a method is provided to align the laser beam output from a laser module so that it is perpendicular to the main shaft. In one method, the low cost laser diode module is installed in a laser module housing which is attached to a main shaft. The main shaft defines a rotational axis of the laser level and is mounted in the top surface of an outer casing. The top of the outer casing is machined so that it is flat. When mounted, the main shaft is perpendicular to the top surface of the outer casing and the laser beam is parallel to the top surface of the outer casing. Inside the outer casing, in one embodiment, the main shaft is installed in an oil-less bearing coupled by a pulley to the shaft of a motor whose rotational axis is parallel with the main shaft. The motor causes the

laser module housing to rotate. A spirit level can be used as a reference to level the top surface of the outer casing. Once the top surface of the outer casing is level, the rotating laser beam is capable of generating a level reference plane of light. The outer casing is mounted on an adjustable base plate. The outer casing can be mounted on the base plate in a number of orthogonal orientations to generate, for example, horizontal, vertical, and plumb reference planes of light.

It is an object of the present invention to provide a means to oscillate the module housing. This creates a reference line of light which is significantly more visible than the fore-mentioned reference plane. The reference line of light is rotatable around the rotational axis of the laser level. The reference line of light is rotatable both manually and automatically via remote control.

It is another object of the present invention to provide a means to install a plurality of laser diode modules into the module housing. When the laser module housing is rotated or oscillated, then a respective reference plane or reference line generated will be significantly more visible ~~compared with a laser module housing~~ which has just a single laser diode module installed. When the module housing is not rotating or oscillating, the user may project a plurality of laser light dots on any flat target. The user then may then draw a level line by connecting the laser dots on the target surface.

It is another object of the present invention to provide a means to simultaneously generate a perpendicular cross-hair reference line of light relative to the reference plane of light. The perpendicular reference line of light is produced by an accessory to the laser level. The accessory consists

of two mirrors positioned to reflect a portion of the reference plane of light. The first mirror reflects a portion of the reference plane ninety degrees into the second mirror. The second mirror reflects the laser beam another ninety degrees and generates a perpendicular cross hair reference relative to the original reference plane of light. The cross hair reference can be generated anywhere along the original reference plane of light by rotating the accessory around the laser levels rotational axis.

Brief Description of Drawings:

Figure 1 is a diagram showing the effect of an inaccurate beam alignment.

Figure 2 is a diagram of a simple collimating optical system.

Figure 3 is an illustration of typical alignment tolerances found in standard low cost laser diode modules.

Figure 4 is a diagram of a typical laser beam path found in standard low cost laser diode module.

Figure 5 is an illustration of random laser beam paths emitted from a standard low cost laser diode module.

Figure 6 is an illustration of the front view of an alignment target.

Figure 7 illustrates a front view of an alignment station.

Figure 8 illustrates a side cross-sectional view of a laser level without a cap.

Figure 9A illustrates a front cross-sectional view of the laser level with a cross hair accessory attached.

Figure 9B illustrates the cross-hair accessory.

Figure 10 illustrates a side cross-sectional view of an embodiment of a cap.

Figure 11 illustrates a front cross-sectional view of another embodiment of a cap.

Figure 12 illustrates a partial cut away view of the top of the laser level with a cap installed.

Figure 13A illustrates a cross sectional view of a possible orthogonal orientation of a case.

Figure 13B illustrates a partial cut away view of another possible orthogonal orientation of a case.

Figures 14A-D illustrates the oscillation movement of the laser level.

Detailed Description of the Preferred Embodiments:

A laser level includes a laser beam that is rotated around a rotational axis. The optical system is extremely important to a laser level because the

optical system is what manipulates the laser beam so that it can be aligned precisely perpendicular to the rotational axis of the laser level. It is important that the laser beam can be therefore aligned to be exactly perpendicular to the rotational axis. A properly aligned laser beam will create a level plane of the same height from a reference no matter how far or how close the target surface is from the laser level. When a laser beam that is not aligned to be perpendicular to the rotational axis, it will create a reference line which varies in height depending on how far or how close the target is away from the laser level instrument.

Figure 1 illustrates a properly aligned laser beam 122 and an improperly aligned laser beam 124. Beam 122 is perpendicular to the Z-axis of rotation. Beam 122 is projected on two vertical targets: target 128 and target 130. Target 128 is some distance "x" from the laser source 126. Target 130 is an additional distance "delta x" away from target 128. The difference in vertical height between the point where the beam 122 hits target 128 and the point where the beam 122 hits target 130 is zero. Beam 124 is not perpendicular to the rotational axis Z. Beam 124 is some angle theta away from the perpendicular. Beam 124 is projected on the same targets 128 and 130. The difference in height between the point where beam 124 will hit target 128 and the point where the beam 124 will hit the target 130 will be different by some distance "delta H". This will create significant problems. For example, if a laser level is located at the center of a square room and the beam is aligned like beam 124, the laser level will be incapable of drawing a correct level reference line on the four walls. This will typically make the laser level unusable for many applications.

One attempt to properly align the laser beam with respect to the rotational axis Z involves use of relatively expensive optical components and time consuming alignment procedures. Figure 2 is a schematic of such a representative system. The optical axis O is the central axis of the lens 120. The mechanical axis M is the central axis of the outer housing 116 encasing the laser diode source 114 and the associated lens 120. From a practical perspective, it is the mechanical axis M which must be aligned perpendicular to the rotational axis Z and the beam 118 should be collimated with respect to the mechanical axis M. However, a meticulous alignment process is required to produce the collimated beam 118. The optical axis O of the lens 120 needs to be aligned with the mechanical axis M of the housing 116. The laser diode source 114 must be then aligned on the optical axis O. In short, the laser diode source 114 and the lens 120 must be aligned so they are concentric with respect to each other. Third, the laser diode source 114 must be one focal length F from the lens 120 along the optical axis O. The lens 120 required in such a collimating system is relatively expensive because it needs to be relatively free of lens defects such as spherical aberrations, coma, and astigmatism.

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In order to make an affordable laser level the cost of the optical system including the lens must be reduced and the cost of aligning the optical system must be lowered. The present invention achieves this cost reduction by a method to adapt a standard low cost, non-precision optical system so that it is usable in a precision laser level instrument.

In one embodiment, the present invention employs a low cost laser diode module such as that used in laser pointers. These laser diode modules include a laser diode source and an optical system integrated in an outer

housing. The optical components are inexpensive and the alignment process is quick and simple. A standard low cost laser diode module consists of a laser diode source, a printed circuit board for mounting the source, an inexpensive converging lens and an outer housing. One suitable laser diode module is the VLM-670 available from Quarton Company of Taipei, Taiwan.

Figure 3 illustrates the alignment tolerances found in a typical low cost standard laser diode module 131. In a typical manufacturing process for these laser diode modules, the laser diode 132 is glued to the printed circuit board 134. The printed circuit board 134 with the laser diode 132 is installed into the outer housing 136 along with the lens 140. The lens 140 and laser diode 132 are then adjusted so that the beam 138 focuses on a target (not shown), for example, 5-10 meters away from the laser diode 132. Little attention is paid to placing the laser diode 132 one focal length from the lens or aligning the laser diode 132 so that it is concentric to the lens 140. The mechanical axis M and the optical axis O are typically not ~~aligned.~~ The beam 138 is typically not collimated relative to the mechanical axis M.

Figure 4 shows a typical laser beam 146 found in a standard low cost laser diode module 149. Instead of collimating with respect to mechanical axis M the beam 146 ~~will likely converge~~ on a spot 147 some radial distance R ~~from the mechanical~~ axis M.

The optical system found in a standard low cost laser module is believed to be unusable in a typically laser level instrument application. Each laser diode module will produce a laser beam which will vary in some

unpredictable angular relationship with respect to the mechanical axis M. Figure 5 illustrates this relationship ~~with three laser diode modules 156,~~ 158, and 160 aligned on mechanical axes M1, M2, and M3 and emanating laser beams 150, 152, and 154.

The present invention provides a method for aligning the beam emanating from a standard low cost laser diode so that it is perpendicular to the rotational axis of a laser level. In one embodiment, the method includes use of an alignment target 81 and an alignment station 83 as shown in Figures 6-7. In a preferred embodiment, the alignment target 81 is shown on a vertical wall in the plane of the sheet (Figure 6). The alignment target 81 has a vertical reference line 80 and a horizontal reference line 82 which are perpendicular to each other. The vertical reference line 80 is assumed to be normal to the earth's surface. The size of the alignment target 81 is preferably 4 feet in diameter, though the exact size is not critical.

Referring to Figure 7, a preferred embodiment of an alignment station 83 is shown. For example, in Figure 7, the alignment station 83 includes a rigid table 84 with a flat upper surface 89 which can be adjusted to be level and parallel to the earth's surface and a rigid alignment fixture 86. The alignment fixture 86 is securely mounted on the table 84 and has a hole 88 which is perpendicular to the table 84. The module housing 36 includes a main cylindrical shaft 37 which extends into the hole 88 in a snug manner so that the shaft 37 is normal to the earth's surface. The main shaft 37 is hollow to permit passage of wire leads (not shown) to the laser diode modules 38 and 39. The module housing 36 and main shaft 37 are preferably machined out of single block of metal such as stainless steel.

The main shaft 37 extends from the middle of the module housing 36 and defines a Z-axis of rotation. A slot 7 is machined in the center of the module housing 36 and is aligned with the Z-axis. The module housing 36 preferably includes two cylindrical holes 91 and 93 for mounting two laser diode modules 38 and 39. As shown, the Z-axis of rotation defined by the shaft 37 is perpendicular to the horizontal axis H which intersects with the center axis of the cylindrical holes 91 and 93.

The alignment target 81 and alignment station 83 are preferably at least about 15 meters from each other although the exact distance is not critical. The alignment station 83 and the alignment target 81 are aligned so that the horizontal reference line 82 of the alignment target 81 (Figure 6) and the horizontal axis H of the module housing 36 are parallel to one another and in the same horizontal level plane with respect to the earth. One method to ensure the horizontal axis H and the horizontal line 82 are properly aligned is to use an auto-leveling laser level such as the 1142 XL LaserLevel manufactured by Spectra-Physics Corporation of Dayton, Ohio. The vertical reference line 80 of the target 81 will then be perpendicular to the table 84 of the alignment station 83 and parallel to the main shaft 37. The laser diode modules 38 and 39 are then inserted in the holes 91 and 93 in the module housing 36. The laser diode modules 38 and 39 fit snugly into the holes 91 and 93 of the module housing 36 but are still rotatable within the module housing 36. A laser diode module 38 is powered so that a laser beam strikes the target 81 (Figure 6) and causes a laser beam spot 85 to appear on the target 81. The laser beam spot 85 is used as an illustration. The actual laser beam spot 85 emitted by any given laser diode module will be typically located randomly somewhere on the target 81. It should be noted before the laser diode module 38 is powered the exact location of the

spot will not be predictable based on the orientation of the module 38 due to three factors: the non-centration between the laser source and the converging lens, the random distance between the laser source and the converging lens and the random alignment of the optical axis relative to the mechanical axis. As ~~the laser diode module 38 is rotated~~ inside the module housing 36 the laser beam spot 85 will rotate correspondingly. The laser ~~diode module 38 is rotated until the laser beam spot~~ 85 is centered along the horizontal reference line 82 of the target 81. At this point the position of the laser diode module 38 is fixed within the module housing 36 by a strong adhesive such as LocTite 640 made by LocTite of Cleveland, Ohio. In a preferred embodiment, two laser diode modules 38 and 39 will be rotated so the position of each laser beam dot generated by each laser diode module 38 and 39 will each be along the horizontal reference line 82. When both laser beam dots are adjusted in this manner both laser beams emitted from the laser diode modules 38 and 39 will be perpendicular to the main shaft 37.

Figure 8 illustrates a cross-sectional view of an embodiment of the laser level 1 not having a cap in place and taken along line A-A of Figure 12. Figure 8 shows the laser level 1 with four major components: an upper case 2, a lower case 4, a base plate 54, and a wall mount 50. The upper case 2 and the lower case 4 are both hollow in the middle. Each of the four major components should be made of a rigid material such as injection molded ABS plastic. The upper case 2 includes a flat upper surface 3 upon which rests a cap such as that shown in Figures 10-11. An alternative embodiment includes a flat upper surface 3 that is cast out of metal and rigidly attached to the upper case 2. A circular orifice 5 is bored into the top surface 9 of the upper case 2. The orifice 5 is perpendicular to the

upper surface 3. An oil-less bearing 28 is pressed snugly into the orifice 5 so the bearing 28 is fixed with respect to the upper case 2. One suitable bearing is a bronze-oil impregnated bearing part no. B6-54 available from Motion Industries of Santa Clara, California. The module housing 36 contains laser diode modules 38 and 39 which are aligned with respect to the shaft 37 as described earlier. The module housing 36 also includes a main shaft 37 which is inserted into the oil-less bearing 28. One suitable material for the main shaft 37 is type 303 stainless steel. The outer surface of the main shaft 37 is machined and polished so that it is smooth. The resulting fit between the oil-less bearing 28 and the shaft 37 is snug, but the shaft 37 can be freely rotated inside the oil-less bearing 28. A retainer ring 30 is used to retain a main pulley 24 to the bottom of the oil-less bearing 28. One suitable retainer ring 30 is a 3/8 inch stainless steel retainer ring part no. Q2-37 available from Motion Industries of Santa Clara, California. A suitable main pulley 24 can be made from nylon. The main pulley 24 is rotated around the oil-less bearing 28.

The main pulley 24 secures a set of upper-magnets 25. A suitable set of magnets 25, for example, are the M35,500, 1/4 inch diameter, 3/16 inch thick magnets made by Edmund Scientific Company of Barrington, New Jersey. The main pulley 24 is coupled to a small pulley 20 by means of a pulley belt 22. A suitable pulley belt is the STS-70-226, 1/16 inch diameter "O" ring manufactured by Winfred M. Berg Inc. of East Rockaway, New York. A suitable small pulley 20 can be made of nylon. The small pulley 20 is fitted to the shaft 100 of a DC motor 14. A suitable DC motor is the 273-273, 65 mA, 1.5v to 4.5v DC motor with gear available from Radio Shack of Milpitas, California. A frame 16 (Figure 9A) attaches the DC motor 14 to the interior wall of the upper casing 2 by

the bolts 17 and 101. A suitable frame is molded out of same injection molded ABS plastic used, for example, for the upper case 2. A free wheel 32 shown in Figure 8 is rigidly attached to the main shaft 37 by a nylon screw 34. A suitable free wheel 32, for example, is fabricated out of nylon. A suitable nylon screw 34 is a 6/32 - 1/2 inch nylon screw. The screw 34 is hollow in the center which permits passage of an electrical lead 19. The electrical lead 19 is soldered to a ball contact 35 which is supported by the head of the screw 34. The ball contact 35 is made of stainless steel and is polished to be smooth to ensure continuous smooth electrical contact with a brush contact 18.

The free wheel 32 holds a set of lower magnets 26. A suitable set of lower magnets 26 are the M35,500, 1/4 inch diameter 3/16 inch thick magnets made by Edmund Scientific Company of Barrington, New Jersey. The lower magnets 26 are substantially aligned with the set of upper magnets 25 in the main pulley 24. The polarity of the upper magnets 25 and lower magnets 26 are oriented such that they are attracted to one another. As the DC motor 14 rotates the small pulley 20 rotates the pulley belt 22 which drives the main pulley 24. The rotation of the main pulley 24 and the attractive force between the upper magnets 25 and the lower magnets 26 will cause the free wheel 32 to rotate which causes the main shaft 37 and the module housing 36 to rotate.

An alternative embodiment is to orient the magnets 25 and 26 so they repel one another.

As shown in Figure 8, the ball contact 35 rests on top of the brush contact 18. The ball contact 35 is able to rotate freely relative to the brush contact

18. A suitable brush contact 18 can be fabricated out of stainless steel. A spring 162 supports the brush contact 18. A screw 164 supports the spring 162. In alternative embodiment, the suitable brush contact 18 includes a bowl shaped round smooth upper plate (not shown) rather than a flat surface which makes continuous receiving contact with the ball contact 35. In either embodiment, electrical continuity exists between the brush contact 18 and the ball contact 35 to provide electrical power through the electrical leads 19 to the laser diode modules 38 and 39. Suitable laser diode modules 38 and 39 are part no. VLM-670 available from Quarton Company of Taipei, Taiwan. The screw 164 is preferably screwed into the frame 16. A wire (not shown) is used to connect the brush contact 18 with a positive terminal of a set of batteries 12. The ground path for the laser diode modules 38 and 39 is provided by the stainless steel outer casing of the laser diode modules 38 and 39. The ground path is established by conductance between the stainless steel main shaft 37, the stainless steel oil-less bearing 28, and a wire (not shown) connected to the negative terminal of the batteries 12.

A LED indicator 10 is mounted to the front of the upper case 2. A suitable LED is the part no. 276-025 available from Radio Shack of Milpitas, California. When the power is applied to the laser diode modules 38 and 39 the LED indicator 10 lights up. A switch 8 is also mounted to the front of the upper case 2. A suitable switch is the part no. 275-634 available from Radio Shack of Milpitas, California. The switch 8 applies power to the laser diode modules 38 and 39. A second switch (not shown) is used to apply power to the DC motor 14. The lower case 4 is attached to the upper case 2 by means of screws (not shown). The bottom surface of the lower case 4 is flat. When properly attached to the upper case 2, the

bottom surface of the lower case 4 is parallel to the top surface 3 of the upper case 2. The lower case 4 contains the set of six batteries 12 used to power the laser level 1. A suitable battery for the set is size "AA" alkaline battery. A removable bottom cover 6 for the lower case 4 is used to provide access to the batteries 12.

Figure 9A illustrates a front cross-sectional view of the laser level 1 with a cross-hair accessory 90. The cross-section of the laser level 1 is taken along line B-B of Figure 12. The base plate 54 has two rails 55, 59 machined so that they are parallel and level with respect to each another. The bottom of the lower case 4 has two lower slots 57, 61, which are machined to be parallel and level to one another and parallel to the upper surface 3 of the upper case 2. The lower case 4 is mounted on the base plate 54 by sliding the lower case 4 onto the base plate 54 using the lower slots 57 and 61 and the parallel rails 55 and 59 as guides. The bottom and top surfaces of the base plate 54 are machined to be flat. Two threaded posts 102 and 104 are attached to the base plate 54 by each using a retainer ring (not shown). The threaded post 102 is attached the center of the outer left edge of the base plate 54. The threaded post 104 is attached the center of the outer front edge of the base plate 54. Suitable threaded posts 102 and 104 can be fabricated out of stainless steel. The adjustable wheels 58, 60 are threaded respectively into the posts 102, 104 to adjust the level of the base plate 54. A suitable adjustable wheel is the part no. 9330 screw with knurled knobs available from Rutland Industries of San Jose, California. One end of the universal joint 52 is attached to preferably the bottom right part of the base plate 54. The opposite end of the universal joint 52 is attached to the wall mount 50 so that the base plate 54 is able to pivot around the universal joint 52 when the adjustable wheels 58, 60 are

rotated for height adjustments. A suitable universal joint 52 is the spherical bearing RJS-4 available from Motion Industries of Santa Clara, California. A threaded hole 56 for conventional camera or construction tripod (not shown) is bored into the bottom surface of the wall mount 50 to allow for convenient mounting on a standard camera or construction tripod. Two chassis holes 51 and 53 are drilled into the side surface of the wall mount 50 so that the laser level 1 can be conveniently mounted to a flat surface. In a preferred embodiment, the centerline of the chassis holes 51, 53 define a line (not shown) within the plane where the laser level beam will be projected. For example, if the laser level 1 is used to define a horizontal line on a wall, the laser level 1 can be mounted on an opposite wall at the same height by lining the holes 51, 53 on that line.

As shown in Figure 9A, the cross-hair accessory 90 fits on the upper surface 3 of the upper case 2. The accessory 90 has a first mirror 92 aligned at the height of the projected laser beam 96. The first mirror 92 is angled at 45 degrees and reflects the laser beam 96 into the second mirror 94. As shown in Figure 9B, a front view of the cross-hair accessory 90 taken along the line F-F, the second mirror 94 is angled 45 degrees and reflects the laser beam 90 degrees. Suitable mirrors 92 and 94 are the M31,011 mirrors available from Edmund Scientific of Barrington, New Jersey. Consequently, a laser level 1 projecting a rotating horizontal laser beam 96 into the cross-hair accessory 90 will project a vertical line perpendicular with respect to the horizontal plane.

Figure 10 illustrates a cross-sectional view of one embodiment of the cap 76 of the present invention. Cap 76 fits on the upper surface 3 of the upper case 2 (Figure 8). Cap 76 is circular in shape. A suitable cap 76

can be fabricated out of type 6061 aluminum. When properly mounted on the upper surface 3, the C-axis shown in Figure 10 will align with the Z-axis shown in Figure 8. The inner wall of the cap 76 will fit snugly against a outer wall 172 of a middle stair 170. The cap 76 is rotatable around the middle stair 170. The middle stair 170 is preferably fabricated out of a rigid material such as that used for the upper surface 3. The top and bottom surfaces of cap 76 are flat and machined to be parallel to each another. A circular spirit level 42 is mounted flush with the top of the cap 76. A suitable spirit level 42 is the M42,763 available from Edmund Scientific Company of Barrington, New Jersey. Cap 76 is placed over the module housing 36 so that the bottom surface of the cap 76 is flush with the upper surface 3 of the upper case 2. A linear spring 72 is perpendicularly pressed into the side to the shaft 75. A suitable spring 72 can be fabricated from 0.03 inch thick spring steel. A suitable shaft can be fabricated out of stainless steel. The length of the linear spring 72 extends from the shaft 75 to near the inner wall of the cap 76 and overlaps with a spacing contact 74 rigidly attached to the inner wall of the cap 76. A suitable spacing contact 74 can be fabricated out of aluminum.

The present invention permits a number of different modes of operation using cap 76. The cap 76 shown in Figure 10 is placed on the laser level 1 shown in Figure 8. Using the spirit level 42 as a reference, the laser level 1 is correctly oriented with respect to earth by using the adjustable wheels 58 and 60. An alternative embodiment places a spirit level or a plurality of spirit levels on the upper surface 3 of the main case 2 shown in Figure 8. After the laser level 1 has been leveled, the cap 76 is removed. The laser diode modules 38, 39 are then powered by toggling on an electrical switch

8. In the dot mode, two laser level beam dots appear on a flat target surface and can be used by an operator to draw a level reference line.

In the plane mode, a second switch (not shown) is toggled on and the DC motor 14 is activated. The DC motor 14 rotates the main pulley 24 and the upper magnets 25 as described earlier in connection with Figure 8. Because the lower magnets 26 are attracted to the upper magnets 25, the freewheel 32 attached to the lower magnets 26 will rotate. Since the free wheel 32 is attached to the main shaft 37, the module housing 36 will also rotate. Since the beams emitted by the laser diode modules 38, 39 in the module housing 36 are aligned perpendicular to the main shaft 37, the laser level 1 will generate a level plane of reference light.

In the short line mode, if the cap 76 is placed on the laser level 1, the module housing 36 will be coupled to the shaft 75 by the shaft tip 77 (Figure 10) extending into the slot 7 (Figure 8) in the module housing 36. When the shaft tip 77 and the slot 7 are properly coupled, the laser diode modules 38 and 39 will emit out of a opening 110 of the cap 76. When the module housing 36 is rotated the linear spring 72 will be obstructed by the spacing contact 74. When this happens the entire module housing 36 will reverse the direction of rotation momentarily because the linear spring 72 creates enough force to separate the lower set of magnets 26 from the upper set of magnets 25. The module housing 36 will then change back to the original direction of rotation when the upper and lower magnets 25, 26, are aligned and rotating together. This ongoing reversal of rotational direction will cause a short, very bright reference line to be generated on a flat target surface. The laser level 1 used without the cap 76 will generate a 360 degree reference plane. With the cap 76, the laser level 1 will

generate a short bright line which is useful in applications with brighter ambient light.

Figure 11 illustrates a cross-sectional view of another embodiment of the present invention. This embodiment includes a cap 78 which fits on the upper surface 3 of the upper case 2. When properly mounted on the upper surface 3, the D-axis shown in Figure 11 will align with the Z-axis shown in Figure 8. The top and bottom surfaces of cap 78 are flat and machined to be parallel to each another. A circular spirit level 43 is mounted flush with the top of the cap 78. A suitable spirit level 43 is the M42,763 available from Edmund Scientific Company of Barrington, New Jersey. Cap 78 is placed over the module housing 36 so that the bottom surface of cap 78 is flush with the upper surface 3 of the upper case 2 (Figure 8). A ruling shaft 70 is attached to the bottom of the cap 78 by means of a retainer ring 71. A suitable ruling shaft 70 can be fabricated out of stainless steel. The ruling shaft 70 is aligned along the D-axis. At the end of the ruling shaft 70 is a ruling shaft tip 79. When the cap 78 is properly fitted to the upper case 2, the ruling shaft tip 79 fits into the slot 7 (Figure 8).

As shown in Figures 11 and 14A, a pivot arm 98 is attached to the ruling shaft 70. Figures 14A-D illustrate the oscillation mode of the laser level 1. Figure 14A is a partial cross-sectional view taken along the line G-G of Figure 11. The pivot arm 98 is preferably metal and cylindrical shaped. A groove 106 is machined into the pivot arm 98. The groove 106 is machined to snugly fit a round peg 99. The round peg 99 is attached near an outside edge of an eccentric wheel 66. A suitable eccentric wheel 66 and the peg 99 can be fabricated out of nylon. The outer edge of the

eccentric wheel 66 includes gear teeth. The center of the eccentric wheel 66 with gear teeth is attached to a secondary shaft 67. The secondary shaft 67 is attached to top surface of the cap 78 by means of a retainer ring 73. A suitable secondary shaft 67 can be fabricated out of stainless steel.

As shown in figure 11, a motor 62 drives a gear assembly 64, for example, in the clockwise direction. The gear assembly 64 is coupled with the outer gear teeth of the eccentric wheel 66. A suitable motor 62 and gear assembly 64 is the DC motor with gear assembly part no. S-148 available from Futaba of Tokyo, Japan. Figures 14A-D illustrate how rotational movement by an eccentric wheel 66 converts into an oscillatory motion of a beam 108 projected by laser diode modules 38, 39. As the eccentric wheel 66 rotates in the counter-clockwise direction, the pivot arm 98 pivots about the ruling shaft 70. Figure 14A illustrates the initial position of the pivot arm 98 relative to the ruling shaft 70. The peg 99 in the groove 106 is in the 3 o'clock position. As the eccentric wheel 66 rotates counter-clockwise 90° around the secondary shaft 67, the far end of pivot arm 98 moves to the left in response to movement of the peg 99 which has moved to the 12 o'clock position as shown in Figure 14B. Figure 14C shows the peg 99 in the 9 o'clock position after the wheel 66 rotates another 90° counter-clockwise. Finally, Figure 14D shows the peg 99 in the 6 o'clock position after the wheel 66 rotates another 90° counter-clockwise. The corresponding oscillatory pendulum-like movement of the laser beam 108 is shown in Figures 14A-D.

Figure 12 illustrates a partial cut-away top view of the cap 78 installed on the laser level 1. The upper half of the Figure 12 above line A-A is cut away to show the mechanisms hidden beneath the cap 78. The outer gear

teeth of the eccentric wheel 66 is coupled with the gear assembly 64 which is driven by a DC motor 62. As shown, the DC motor 62 is mounted on the left side of the cap 78. When the DC motor 62 is activated it will cause the pivot arm 98 to pivot about the ruling shaft 70 as discussed earlier.

When the cap 78 is properly fit on the top surface 3 of the upper case 2 the ruling shaft tip 79 (Figure 11) will fit into the slot 7 (Figure 8) and will oscillate the module housing 36. Another DC motor 44 is mounted on the right side of the cap 78. The shaft of the DC motor 44 is fitted with a gear 46 (Figure 11). A suitable DC Motor 44 with gear 46 is part no. S-148 available form Futaba of Tokyo, Japan. When the cap 78 is placed on the upper surface 3 of the upper case 2, the gear 46 will mesh with an internal gear 48 (Figures 8 and 12). A suitable internal gear 48, for example is part no. SIE632-048A120 available from Designatronic, Inc. of New Hyde Park, New York. When the cap 78 is installed on the laser level 1 and the DC motor 44 is activated, the cap 78 rotates around the D-axis as shown in Figure 11.

In another embodiment, the laser level 1 can be remotely activated by a printed circuit board (PCB) receiver 40 which is mounted into the cap 78. One suitable PCB receiver 40 is made by Ming Engineering Corporation of Los Angeles, California, which will receive an RF signal preferably 30 Mhz sent by a compatible transmitter (not shown) also made by Ming Engineering Corporation. The signal is decoded by the receiver 40 and the DC motor 44 is activated via a conventional small relay (not shown).

In still another alternative embodiment of the cap 78, the PCB receiver 40 and the DC motor 44 with gear 46 may be eliminated. In this case, the operator can rotate the cap 78 manually.

As shown in Figure 12, power is provided to the cap 78 via a metal voltage ring 176 and a metal ground ring 174 which are attached to the upper surface 3. Two leads (not shown) attach the voltage ring 176 and the ground ring 174 to the batteries 12 shown in Figure 8. Another pair of leads (not shown) are attached to the bottom surface of the cap 78 and provides power for the DC motors 62 and 44 shown in Figure 11.

Cap 78 shown in Figure 11 is placed on the laser level 1 shown in Figure 8. The ruling shaft tip 79 will extend into the slot 7 shown in Figure 8. Thus, the ruling shaft 70 will be coupled with the module housing 36 and the laser diode modules 38 and 39 (Figure 8) will emit out of an opening (not shown) in the cap 78. Using the spirit level 43 as a reference, the laser level 1 is leveled using the adjustable wheels 58 and 60. After the laser level 1 has been leveled, the laser diode modules 38, 39 are powered by toggling on electrical switch 8. A second switch (not shown) is toggled on and the DC motor 62 is activated. This causes the eccentric wheel 66 to oscillate the ruling shaft 70 back and forth as described in connection with Figures 14A-D. Since the ruling shaft 70 is coupled with the module housing 36 the module housing 36 will also oscillate back and forth as described earlier. With the laser diode modules 38, 39 activated, this oscillation will produce a long reference line on a flat target surface. By manually rotating the cap 78 the long reference line can be rotated 360 degrees around the Z-axis shown in Figure 8. An automated means of rotating cap 78 is provided by activating the second DC motor 44. The

small gear 46 will rotate against the internal gear 48 fixed to the upper surface 3 of the laser level 1 causing the cap 78 to rotate. The second DC motor 44 can be also activated by remote control by a PCB receiver/transmitter as discussed above.

Figures 13A and 13B illustrate two orthogonal orientations of the laser level 1. All sides of the upper case 2 and the lower case 4 are flat and perpendicular to the upper surface 3. The base plate 54 is machined to be flat. The upper case 2 and the lower case 4 can be place in the orientations shown in Figures 13A and 13B. This allows the operator to draw two reference planes in addition to the horizontal plane. For example, the laser level 1 can provide for a vertical reference plane that is perpendicular to the horizontal reference plane and a plumb reference plane that is perpendicular to both the vertical reference plane and the horizontal plane.